Chapter 4
Assessment of Soil Quality in Urban Green Areas of Two Russian Cities by Means of Chemical and Biological Methods

A. Kamalova, A. Gordeev, P. Galitskaya, and S. Selivanovskaya

Abstract The quality of urban soils in green zones is a result of combination of natural processes, anthropogenic pollution and management. The elevated presence of heavy metals in soils of the urban environment has been recognized as an important source of metal intake into the human body. The aim of this study was to evaluate the concentration of heavy metals in soil of 24 parks and public gardens obtained in Kazan (with 1 Mio citizens) and its satellite city Zelenodolsk. The soil samples and two different herbaceous perennial plant *Plantago major* and *Trifolium repens* were analyzed for 5 metals (Cd, Cu, Pb, Ni, Zn) using ICP-MS. We also determined the physiological profiles of microbial communities using the Biolog Ecoplate multi-substrate testing method and the diversity of plants in urban green zones. The results from the study showed that the heavy metal concentration in soil samples ranged between 0.06 to 0.70 mg/kg, 0.82 to 30.02 mg/kg, 0.06 to 66.42 mg/kg, 9.91 to 71.33 mg/kg and 4.41 to 24.51 mg/kg for Cd, Pb, Cu, Zn, Ni, respectively. In average, the concentrations of the metals in soils did not exceed the levels recommended by WHO. In plants, the concentration of Zn exceeded the recommended levels by 10–25 times. The Shannon–Wiener diversity index for plant communities varied from 2.32 to 2.96, and for microbial community (AWCD)—from 0.143 to 1.695. No significant differences between the diversity indices for large and satellite cities were found. No correlation between the level of metal contents and diversity indices was found.

Keywords Heavy metals · Urban Park · Plant diversity · Functional diversity of soil microbial community

A. Kamalova (✉) · A. Gordeev · P. Galitskaya · S. Selivanovskaya
Kazan (Volga region) Federal University (KFU), Kazan, Russia
e-mail: AlinaRAhtyamova@kpfu.ru

4.1 Introduction

The urban environmental quality is of importance because the majority of people now live in cities (Tresch et al. 2018). Urbanized areas are rapidly expanding at the expense of natural habitats and the corresponding human population shift. It has resulted in landscapes created by humans–urban green spaces, including parks and public gardens, have become a substitute for the lost environmental spaces (Francini et al. 2018; Yan et al. 2019).

Soil of urban green spaces and provides key ecosystem services for a comfortable living in city (Li et al. 2018). Its quality is one of the components of environmental quality, as with the quality of water and air (Andrews et al. 2002). The world's population is increasingly urbanized, with 55% living in city areas, and predictions of up to 66% by 2050 (Różański et al. 2018). Therefore, interest to urban soils due to the potential impact of this soils on population has recently increased (Morel and Heinrich 2008). This is due to the fact that soils in urban and suburban areas are greatly impacted by human activities. This can have significant consequences for the health of people, plants and soil organisms, as well as the ability of water to penetrate the soil (Page-dumroese 2020).

Urban green spaces (UGS) are defined as areas primarily covered by plants, including trees, grasses and shrubs, that have a direct or indirect positive impact on people's lives by purifying toxic substances and improving the microclimate (Haq 2011). This soils quite different from natural soils due to the high level of human activity, leading to increased pollution, physical disruptions and alterations to the surface. This soils quite different from natural soils due to the high level of human activity, leading to increased pollution, physical disruptions and alterations to the surface. Urban soils are frequently associated with degraded or contaminated soils low levels of soil organic carbon and biological activity (Ajmone-Marsan and Biasioli 2010; Scharenbroch et al. 2005) compared to non-urban soils. Compared to them, urban soils are also influenced by the local microenvironment as well as the process of its formation.

In many places around the world, the chemical environment of soils has been modified due to the rapid urbanization and industrial growth (Johnson and Demetriades 2011). The sources of pollution can be transport (motor exhaust, brake pads, tire wear), domestic activities (such as waste disposal and construction, wastewater), commercial and industrial emissions (including those from metallurgical industry, electronics, chemical plants, fuel combustion) and agricultural activities (such as the use of fertilizers, pesticides and wastewater irrigation) (Argyraki and Kelepertzis 2014; Wei 2018).

Along with polyaromatic hydrocarbons, chlorganic compounds and radionuclides, heavy metals are typical urban pollutants that can be transferred into humans and influence their health (Madrid et al. 2002). Toxic metals, such as Pb, Cd and Cr, are still increasingly accumulating in urban environments, causing concern because urban soils as they easily come in contact with humans, e.g., in the form of suspended dust (Ljung et al. 2006; Sörme et al. 2001). These are pollutants that do not undergo

chemical or biological degradation and therefore can be accumulated in soils or living organisms. Human exposure to heavy metals can occur through ingestion, inhalation and skin contact and in different places, mainly in urban parks (Penteado et al. 2021). Urban soil in parks acts as a sink for pollution of potential toxic elements (PTE) because to the presence of large open exposed areas of soil (Gu et al. 2016; Zhao et al. 2014).

Human outdoor and activities have increased in parks on a daily basis, for benefits to people's health. Particularly during the COVID-19 pandemic period in 2020–2021, parks and public gardens provided an important place for residents (especially children) for outdoor relaxation and entertainment purposes (Brtnický et al. 2019). Children are at higher risk of exposure to pollution due to their frequent contact with soil and other surfaces (Brtnický et al. 2019; Gu et al. 2016; Zhang 2019),, which can lead to contamination through skin contact, inhalation and hand-to-mouth ingestion (Li et al. 2014b), even at low concentrations. Children are more vulnerable to pollution due to their smaller size, developing nervous systems and higher absorption rates. For instance, while the portion of ingested Pb which absorbed an adult's body less than 5%, children can absorb up to 50% due to their less developed gastrointestinal tracts (Maddaloni et al. 1998).

Urbanization also has a specific effect on the plant development and bacterial soil communities due to conversion of native habitats to various forms of land use and habitat loss (McIntyre 2000). Outstanding properties of urban soils are limited aeration and drainage, which can lead to anaerobic conditions, disrupt nutrient cycling and result in elevated temperatures (Bae and Ryu 2017). Excessive concentration of metals above the maximum permissible limit can negatively impact the quality of soil organisms, such as microfauna and macrofauna, as well as ground and drinking water. This can ultimately impact the quality of food (Nganje et al. 2020; Wang et al. 2020). The contamination of urban soils with heavy metals was discovered to have an impact on soil microorganisms, including microbial biomass and diversity, basal respiration rate, physiological profile and the activities of dehydrogenase, sulfatase, glucosidase and phosphatase (Yang et al. 2006).

Urbanization results in the expansion of cities' boundaries, causing greater patchiness in the landscape. This, combined with loss of habitats, is the primary factor contributing to the decline of biodiversity (Grimm et al. 2008). Being the primary green areas of urban landscapes, they represent important biodiversity hotspots in cities (Nielsen et al. 2014). Parks and public gardens are generally composed of grassy areas, with tree and shrub species commonly used that support limited biodiversity, particularly if non-native and less capacity for critical ecosystem services (Aronson et al. 2017).

Comparing small and big cities can be difficult at times because the studies' methodological approaches, including soil fraction, contaminants studied and chemical extractions. The size of the city does not directly determine the level of contamination, as small urban areas can be in close proximity to industrial areas (Gallego et al. 2002) and experience the same anthropogenic pressures as bigger cities. Although

suburban areas don't contribute significantly to industrial pollution, they do contaminate the environment through the disposal of household and yard waste, storm drains, construction activities and materials and traffic (Callender and Rice 2000).

In the present work, quality of soil of urban green areas situated in a Russian big city (over 1 Mio citizens) as well as its satellite small city (about 0.1 Mio citizens)—Kazan and Zelenodolsk, respectively—was studied. Currently, poor information is available about urban soil quality in Russian cities while this country represents about 11.5% of the land on the planet. The study was conducted in summer 2021. The plant and bacterial biodiversity as well as the level of heavy metals pollution were analyzed in the urban green areas investigated.

4.2 Materials and Methods

4.2.1 Study Site

This research was carried out in two Russia cities: Kazan (55°47′19.46″ N 49°07′19.70″ E) and Zelenodolsk (55°50′37.54″ N 48°31′4.22″ E). These cities have significant natural, geographical and industrial aspects. Zelenodolsk is a classic satellite city of the monocentric Kazan agglomeration. The both cities are located on the left bank of the Volga River, and the population of Kazan city is 1,259,173 people (as of January 2022), of Zelenodolsk—99 235 people. The city of Zelenodolsk belongs to the category of medium cities. 145 urban green zones are situated in Kazan, covering about 0.84% of city area. Currently, the area of green common areas in Zelenodolsk is 13.1 m^2/person, which corresponds to the established requirements of at least 7 m^2/person for medium-sized cities (Zakirova and Khusnutdinova 2018).

4.2.2 Estimation of Plant Biodiversity

The species diversity of (sub)urban habitats, including parks and gardens, can be extremelyhigh (Gilbert 1989). The plants in the plot were identified and cover of individual plant and the whole community in the quadrat. From the estimated dominance–abundance of the herbaceous vegetation and for trees and shrubs taxa, the Shannon–Wiener the standard biodiversity index was computed (Hermy and Cornelis 2000). Major herbaceous species in the region include *Achillea millefolium, Dactylis glomerata, Medicago sativa*, *Plantago major, Trifolium repens* and *Urtica dioica.*

4.2.3 Soil and Plant Sampling

Sampling on July—August 2021 involved systematic sampling from 15 parks of Kazan and 9 green zones of Zelenodolsk which selected randomly and situated in different districts of these cities. The characteristics of parks and public gardens both cities are listed in Appendix Table 4.1.

Soils and dust (10—20 g) were taken in three replicates from the right corner, middle and left corner of the main/south entrance of each park from 0 to 5 cm depth. Replicates were stored at ca. 4 °C in zip-lock plastic bags prior to transport back to the laboratory. Soil samples were sieved through 1 mm plastic mesh before analysis. The sizes of the inventory area to determine plant diversity were 10×10 m^2. Three leaves clover samples and plantain from each of the three population were collected in separate zipper bags from each sites. The distance was approximately 4 m and at least 2-m.

4.2.4 Estimation of Heavy Metals Content in Plants and Soils

Before the estimation, plants and soils were air dried till the constant weight. The homogenized plant tissues (0.1 g) were placed in a glass beaker and dissolved with 10 ml of HNO$_3$, gradually heated with a rotation speed of 146 ± 1 rpm at 95–98 °C for 3 h. After the samples were slightly cooled, 1 ml of 33% H$_2$O$_2$ was added and heating of the samples for 1 h. The samples were cooled and 2.5 ml of bi-distilled water was added, filtered and brought to 15 ml (Ji 2012).

For the determination of heavy metals concentration in the urban soil, the homogenized samples (0.5 g) were accurately weighed into 50 ml «Falcon» poly(propylene) centrifuge tubes (pre-cleaned with 10% nitric acid followed by repeated rinsing with bi-distilled water) and 20 ml of 0.1 M HNO$_3$ solution added to the tubes. The tubes were shaken on a shaker at 200 °C with a rotation speed of 30 ± 1 rpm for 24 h. In each batch, a blank sample containing the same reagents was also subjected to the extraction procedure. The extracts were kept in a fridge at 4 °C prior to ICP-MS analyses (Hutton et al. 2004).

4.2.5 Quantification of Soil Heavy Metal Contamination/ Pollution Index (MPI)

The contamination/pollution index (MPI) was calculated as a ratio of a heavy metals concentration to the permissible standard of set out by EU and WHO top soils standards (Lacatusu 2000; World Health Organization (WHO) 1996).

4.2.6   Estimation of Bacterial Activity and Functional Diversity

To investigate of activity bacterial soil communities, the so-called community level physiological profiling has been demonstrated to be effective at observing spatial changes in microbial communities (Doan et al. 2013). Garland and Mills were the first who used the BIOLOG system to characterize microbial communities in soil (Garland and Mills 1991).

Community level physiological profiles (CLPPs) were assessed by the Biolog EcoPlate™ system (Oxoid, Hampshire, England). Biolog Inc., CA, USA). Each 96-well plate consists of three replicates, each one comprising 31 sole carbon sources and a water blank. Soil suspensions (soil 5 g, distilled water 45 ml) were shaken for 30 min at 250 rpm. Tenfold dilutions were performed and aliquots of 140 µl from a 10^{-4} dilution were inoculated into the microplates. The plates were incubated at 25 °C, and color development in each well was recorded as optical density (OD) at 595 nm with a plate reader at regular 24 h-intervals (Gomez et al. 2006).

With the help of the results received, the following parameters were calculated: average well color development (AWCD) (1) and alpha biodiversity Shannon index (2). The formulae used to calculate the indices are presented below:

$$\text{AWCD} = \sum \frac{A_i - A_0}{31} \tag{4.1}$$

where A_i—the optical density within each well; A_0—is the absorbance value of the control well

$$- \sum p_i * \ln_{p_i} \tag{4.2}$$

where p_i—proportional color development of the well over total color development of all wells of a plate.

4.2.7   Statistical Analysis

All measurements were conducted in three replicates. The indexes of alpha diversity calculated for each community were the Shannon–Weaver Index (Takada 1954) and Simpson index (Simpson 1949). Error bars in the figures represent the standard error of means from the replicates. Statistical significance of differences was analyzed using nonparametric criteria such as Mann–Whitney U test ($p > 0.05$). Statistical analysis was performed in Statistica 10.0 software (StatSoft Inc., Tulsa, OK, USA). Graphs were prepared using Microsoft Excel 2019 MSO (Microsoft, Redmond, WA, USA).

4.3 Result and Discussion

4.3.1 Heavy Metals Concentrations in Soils

The soil has the property of absorbing heavy metals as a result of industrial and anthropogenic activities (Ediene and Umoetok 2017). The main environmental standard for metal soil pollution is so-called maximum permissible limits (MPL), i.e., such a content of a pollutant in the soil that does not affect to animals, plants, microorganisms and natural communities as a whole during constant contact or during interaction over a certain period of time (Ediene and Umoetok 2017; World Health Organization (WHO) 1996). According to WHO prescriptions (1996), the MPL for cadmium, lead, copper, nickel and zinc are 0.8 mg/kg, 85 mg/kg, 36 mg/kg, 68 mg/kg, 50 mg/kg of soil and 0.02 mg/kg, 2 mg/kg, 10 mg/kg, 10 mg/kg, 0.6 mg/kg of plant, respectively. The concentration of heavy metals in soils each parks and public gardens is shown on Fig. 4.1a–e.

Anthropogenic activities such as industrial waste disposals, fertilizer application and sewage sludge disposals on land have led to the accumulation of cadmium (Cd) in soil and its leaching under certain soil and environmental conditions (Alloway 2013). The WHO/FAO recommended maximum tolerable intake of Cd is $70\,\mu g\,day^{-1}$. With the estimated half-life of Cd in soil varying between 15 and 1100 years (Kabata-Pendias 2010), its accumulation in the environment and its entry into the food chain are of great concern. In the present study, the determined concentrations of Cd in soils in Kazan parks were in range of 0.17–0.70 mg/kg, while in Zelenodolsk sites, they varied between 0.06 and 0.39 mg/kg (Fig. 4.1a). The highest Cd concentration was recorded for the sample No. 5 in Kazan. The values for Cd across the sampling points do not exceed the 0.8 mg/kg soil range set by WHO and were below the MPL of 3.0, 1.4 and 400 mg/kg set out by EU, UK and USA Standards, respectively, for Cd in soil (Ediene and Umoetok 2017).

We compared our results with the results of other study which estimated the content of heavy metals in a big city and small cities. According to Li. et al., the average concentration of Cd in the urban soils of Copenhagen was 0.84 mg/kg, which is about 5 times higher than the concentration in the reference soil (Li et al. 2014a). The Cd concentrations in urban parks of the third-largest city in China, Guangzhou were ranged 0.028–2.408 mg/kg (Lu et al. 2007). The study paper Kwaterczak et al. presented results of research of Cd distribution in land on playgrounds situated near busy streets in Cracow (Poland). Samples of sand and soil were collected from the most top layer (0–10 cm). Concentration of examined metal was varied from 1.60 to 2.61 mg/kg. The highest concentrations were found in sampling points near the busiest roads (Aleksander-Kwaterczak and Rajca 2015).

Lead (Pb) is accumulating profoundly in the soil through anthropogenic activities (Mulligan et al. 2001). Being a toxic substance and having high transfer rates (from soil to plant), it is therefore studied broadly especially in context to food safety, quality, and biotesting purposes (Uzu et al. 2009). As follows from the Fig. 4.1b, the highest Pb value was revealed in sample No.15 obtained from Kazan—30 mg/kg,
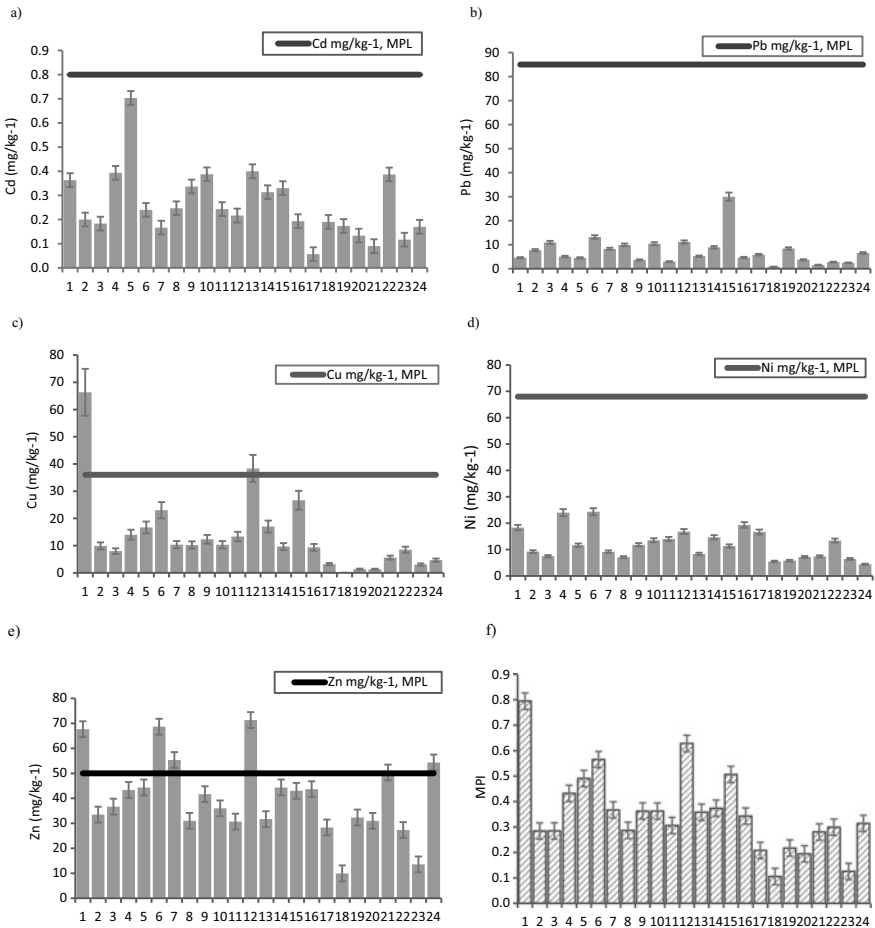
Fig. 4.1 Concentrations of Cd (**a**), Pb (**b**), Cu (**c**), Ni (**d**), Zn (**e**) and contamination/pollution Index (MPI) (**f**) found in urban soils sampled in Kazan (1–15) and Zelenodolsk (9–24) cities (Russia). The black lines indicate the maximum permissible limits according to the WHO standards

the lowest sample No.18 from Zelenodolsk—0.81 mg/kg. The highest value of Pb concentration recorded in the urban park was not higher than the WHO (85 mg/kg) and the 6.4 mg/kg UK standards (70 mg/kg) (Ediene and Umoetok 2017).

Galušková et al. (2014) conducted a study that compared Pb concentrations in Prague and Ostrava parks. The values open areas ranged between 22–213 mg/kg in and 27–125 mg/kg, respectively. The soil pollution may have been contributed by the former brown coal burning in local heating plants (Galušková et al. 2014). According to literature (American Society of Agronomy 1982), highest Pb concentrations were detected in areas with higher population density and more industrial activity. Additionally, Pb pollution may result from the past use of leaded gasoline and emissions from vehicles (Vig et al. 2003). The soil in Durham city's park (North

Carolina, USA) had a lead concentration of 42.1 ± 25.0 mg/kg, which is consistent with other U.S. cities such as Indianapolis and Greensboro, where soils near homes had the highest lead concentration due to exterior house paint. However, in cities like Detroit and New Orleans, soils near roadways pose the highest lead exposure risk due to the contamination of soil being resuspended. Despite this, the soils from city parks and suburban areas showed lower concentrations of metals(loids) that were comparable to the natural levels found in the environment (Wang et al. 2022).

Copper (Cu) is considered as a micronutrient for plants however, it may be toxic in excess quantities (Ediene and Umoetok 2017). Cu particulates are released into the atmosphere by windblown dust and anthropogenic sources, including transport and industrial emissions. Evaluation of Cu in soils of parks and public gardens in Kazan (Fig. 4.1c) showed that values were ranged from 7.97 to 66.33 mg/kg, while the Zelenodolsk soils recorded a mean of 4.12 mg/kg. In soil samples No.1 and No.12, concentrations of Cu were recorded above the maximum permissible limit set by WHO, but were below the MPL of 140, 1.4 and 3.0 mg/kg set out by EU, UK and USA, respectively.

According to Paltseva et al., the concentration of Cu in urban soils (0–20 cm) in cities with over 1 Mio citizens such as Vienna, Moscow, Mumbai (Bombay) was equaled to: 18 mg/kg, 30 mg/kg and 147 mg/kg, respectively. At the same time, in cities with less than 1 Mio people, this value was recorded to 24 mg/kg in Oslo (Tijhuis et al. 2002) and 16 mg/kg in New Orleans (Mielke et al. 2019). In general, in European cities, the concentration of Cu was lower than recommended by WHO, with the exception of the soils from Mumbai (Bombay) (Wang et al. 2022). High concentrations of Cu in the parks of Kazan may be due to the presence in the region of a developed oil production and oil refining industry.

Nickel (Ni) has been considered to be an essential trace element for human and animal health (Nazir et al. 2015). The concentration values obtained for Ni at the urban green areas (Fig. 4.1d) revealed a range of 7.09–24.33 mg/kg, while a mean of 9.56 mg/kg was recorded in Zelenodolsk parks. The overall results indicate that in all the collected soil samples, there was low concentration of Ni found.

According to the literature (Zhong and Jiang 2017), contamination of Ni in urban soils of small cities is higher than in big ones. The value of Ni in Berlin and Melbourne was recorded 8 mg/kg and 15 mg/kg, respectively. While in soils in Baltimore and Novi Sad and Izmit (Turkey), it was 2.8, 28.7 and 39 mg/kg. This suggests that although heavy metal contamination of soil and water has been limited by some government policies, historically produced heavy metals are retained in soil due to their perdurability and degradation durability. In some places, the concentration of nickel has surpassed even the Chinese soil criteria (grade II), and its concentrations also exceed the national quality soil standards (Chen et al. 2020).

Zinc (Zn) is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of Zn can be toxic to the organism (Nazir et al. 2015).

Concentration of Zn in soils samples from Kazan ranged between 30.67 mg/kg to 71.33 mg/kg and 9.97 mg/kg to 54.33 mg/kg obtained from Zelenodolsk, respectively

(Fig. 4.1e). The highest value of 71.33 mg/kg was recorded at No.12, closely followed by values of 68.67 mg/kg of No. 6 and 67.67 mg/kg from the ground No.1.

The quantity of Zn observed at Kazan parks and public gardens greatly exceeded the value of 50 mg/kg recommended by WHO. The level of Zn in sample No. 24 from Zelenodolsk was as well as higher than WHO's recommended limit—54.33 mg/kg.

According to Lee with co-authors, in Hong Kong (about 7.4 Mio citizens), concentrations of Zn ranged from 23 to 930 mg/kg, while in Karachi (about 14 Mio people), it was 99.5 mg/kg (Karim and Qureshi 2014). In small cities such as Zagreb (Croatia), soil contamination with Zn averaged 70 mg/kg (Romic and Romic 2003). The probable sources of Zn contamination primarily include wastewater discharges, followed by automobile transportation and unauthorized dumping of household waste.

To determine the pollution loading of the soil at the various sampling points in parks and public gardens, the MPI was used. According to Lacatusu, the MPI index is the ratio of analyzed concentration of the heavy metal to the maximum allowable limit in the soil (Lacatusu 2000). Despite on the fact that the content of Zn and Cu was exceeded the level recommended by WHO in 5 and 2 parks of 24, respectively, the MPI index in all samples did not exceed 1.0. Therefore, that the level of metal pollution is acceptable. It should be noted though, that the average value of MPI for all metals was higher in Kazan than that in Zelenodolsk (Fig. 4.1f).

4.3.2 Heavy Metals Concentrations in Plants

According to the literature, there is a certain relationship between the chemical composition of plants and the elemental composition of the environment. Different plant parts contain different heavy metals quantities; the highest quantities are in roots and leaves, and the lowest are in fruits and seeds. Some plants species were found to have lower tolerance to toxic metals uptake in parks of soil as they were found to accumulate high concentrations of Cd, Cu, Ni, Pb and Zn (Guala et al. 2010).

In the present study, metals were determined in the two plant species present in all the parks—plantain (*Plantago major* L.) and white clover (*Trifolium repens* L.). The results are presented on Fig. 4.2 and compared with the corresponding WHO standards for plants (Bani et al. 2015). It was found that the concentration of Ni was below the limits in all the plant samples. The concentrations of Cd, Pb and Cu exceeded the limits in 5, 1 and 1 samples, respectively. And the concentrations of Pb were by 10–25 times above the limits in all the plant samples analyzed.
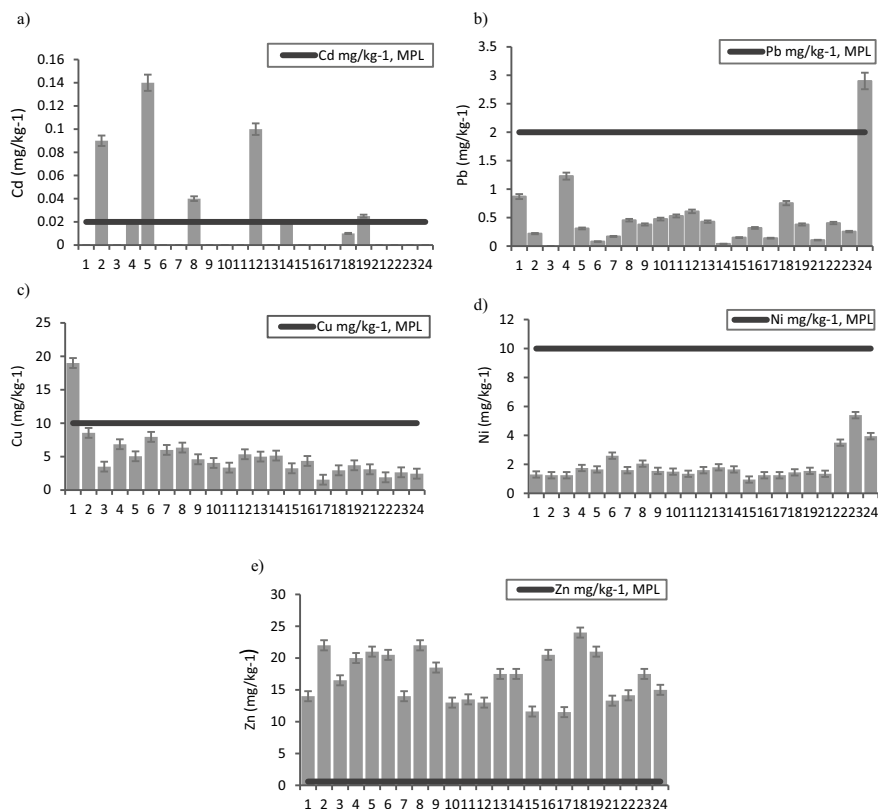
Fig. 4.2 Concentrations of Cu (**a**), Pb (**b**), Cu (**c**), Ni (**d**), Zn (**e**) and Transfer Factor (TF) (Appendix Fig. 4.5) found in plants samples in Kazan (1–15) and Zelenodolsk (9–24) cities (Russia). The black lines indicate the maximum permissible value according to the WHO standards

4.3.3   Plant Diversity and Cover at Various Study Sites

Species diversity is a crucial index mostly employed to evaluate the sustainability at various ecosystem scales and is a multifaceted factor used to estimate a variety of plant indicators (Eshaghi et al. 2009; Ricotta 2005).

In our study, we assessed the biodiversity of plants in parks and squares in Kazan and Zelenodolsk. The amount of grass coverage on the site was determined by the relative occurrence of each species and the number of species in each park.

The Shannon–Wiener index across the parks ranged from 1.51 to 2.43 of Kazan, and from 0 to 2.53 of Zelenodolsk (see Fig. 4.3). According to the literature, urban parks included annual and perennial plants species such as *Zoysia species* (with no petals), *Trifolium repens* (with white petals) and with subcomponent species such as *Sonchus oleraceus, Oxalis corniculate, Cirsium japonicum, Trifolium pretense and Ajuga nipponensis* in Yokohama (Japan) (Tomitaka et al. 2021). In the study,
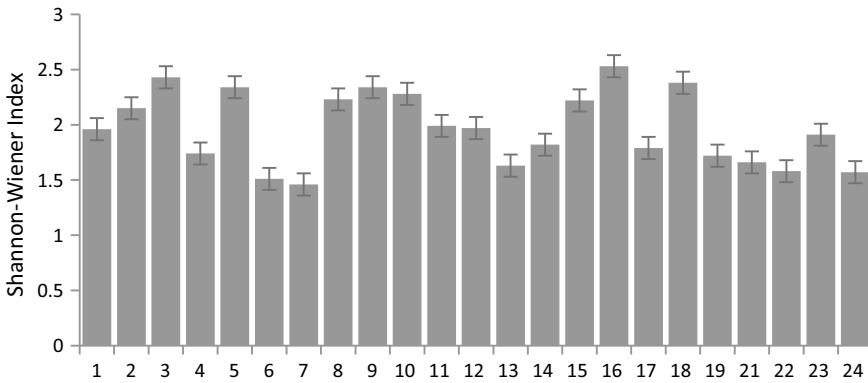
Fig. 4.3 Shannon–Wiener index indicating plant biodiversity in urban green zones in Kazan and Zelenodolsk

Muratet et al. noted that in the park «Parc des Buttes Chaumont» (France), that covers 25 ha. among the native species recorded in the park, the majority were spontaneous species generally considered to be weeds, including *Trifolium repens, Hordeum murinum* and *Veronica chamaedrys* (Scharenbroch et al. 2005). Dominant species in Kazan were *Achillea millefolium, Arctium lappa, Chenopodium album, Convolvulus arvensis, Plantago major* and *Poa trivialis.* Dominant species in satellite city were *Achillea millefolium, Trifolium repens, Artemisia vulgaris, Cichorium intybus, Dactylis glomerata* and *Plantago major.* Dominant species in Zelenodolsk were the same. No significant differences in the species list as well as in the level of Shannon–Wiener indexes between the two cities were found.

We made in attempt to compare the level of metals' pollution of soils with the plant diversity indexes in urban green zones. However, no correlation between the MPI and Shannon–Wiener index was found.

4.3.4   *Bacterial Activity and Functional Diversity in the Soils from Urban Green Zones*

Currently, many ways to estimate the state of the microbiomes in the soils are used. These might be wide range of methods, from estimations of soil microbial biomass and respiration to analysis of soil microbial diversity using next generation sequencing methods. All these methods have their own advantages and disadvantages and should be chosen according to the investigation's main goal. In our study, quick, reproducible method semi-independent on climate conditions were required, and the Biolog Ecoplate® profiling met the requirements (Use of Biolog for the community level physiological profiling (CLPP) of). Using this method, two characteristics of the soil microbial communities were determined—(i) the AWCD indicating the
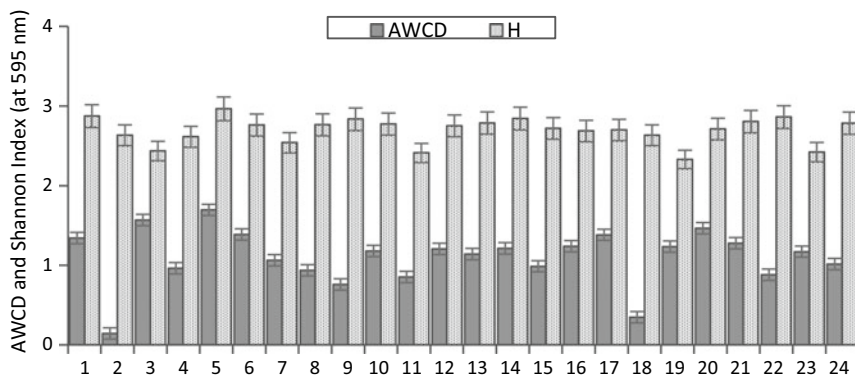
Fig. 4.4 AWCD and the biodiversity Shannon index of microbial communities in the soils of urban green zones as revealed by Biolog Ecoplate® method

intensity of microbial decomposition of different organic substrates means overall microbial activity in the soil samples; and (ii) the Shannon H-index indicating the functional diversity of the microbial community (Fig. 4.4). (Li et al. 2007; Monard et al. 2016).

The highest AWCD index was found in sample No. 5 (1.695 ± 0.340), the lowest one—in sample No. 2 (0.143 ± 0.250), while no correlation was revealed between the level of metal pollution or vegetation diversity and AWCD. The values received correspond with the data obtained by other authors which analyzed soil samples from native vegetation site (roadside verge) and topsoil (0–15 cm deep) (Liu et al. 2012; Xue et al. 2008). It can be suggested that the differences in AWCD are due to differences in organic matter content in the samples, indeed, according to high microbial counts and diversity are usually attributed to rich soils. Thus, in the investigations carried out by Dobrovolskaya et al. and Kovda et al., tight direct correlation between the biological activity of microorganisms and organic matter content in soil was shown. Shannon index showing the level of functional alpha diversity in the community ranged between 2.32 and 2.96. No correlation between the Shannon indices and the AWCD or the level of metal pollution of soil was found (Kumar et al. 2017; Li et al. 2013).

4.4 Conclusion

It can be concluded that in overall, soils from urban green zones in a large (Kazan) and satellite (Zelenodolsk) cities contain Pb, Zn, Cu, Cd and Ni in the concentrations below the WHO standards. Unique cases of exceeding were determined for Cd, Cu and Zn, but the pollution was not complex.

No differences between the green zones and in large and satellite city (biodiversity of plants and microorganisms) as well as no correlation between the metal content and diversity indices were found. It was found that the migration of Pb, Ni, Cu for plantain and white clover don't as intense as in the case of Zn and Cd. Perhaps these urban plants, which grow everywhere, are able to accumulate these metals and also get on the leaves with urban dust.

The absence of a direct stable relationship allows us to conclude that a comprehensive assessment of the state of green areas is applicable, where the content of heavy metals is lower and does not have a significant impact on biodiversity. Accordingly, these measures relate not only to human health, but also more indirect aspects of the quality of life: the structural integrity of the surrounding ecosystems. This work is part of a large research cycle and measurements will be made for other environmental components.

Appendix

See Table 4.1 and Fig. 4.5.

Table 4.1 Characteristics of urban green space at Kazan and Zelenodolsk (Russia)

No	Park name	Location coordinates	Area, % Natural, manicured, unkempt	Park age	Size, m^2	Park description
1	M. Karima public garden	55.763388° 49.14939°	40 / 50 / 10	1	5500	Public garden near a car highway, people walk through every day
2	Public garden(Ippodromnaya street)	55.773302° 49.147741°	60 / 10 / 30	< 10	2680	Small public garden, people walk through every day, next to the kindergarten
3	Public garden of Labour Glory	55.755792° 49.122546°	50 / 10 / 40	25–50	6500	Local garden next to the Kazan Synthetic Rubber Plant (Founded in 1936), realized for the workers. The park is located in a remote area of the city
4	Park Molodozhenov	55.774184° 49.09985°	55 / 30 / 15	25–50	25,000	It rather a big park, but not popular. Next to the river port, there are no playgrounds in the park. This is a remote area of the city
5	Gorkiy Central Park of Culture and Recreation	55.799874° 49.147063°	60 / 40 / 0	85	244,794	Quite big, will require 2–3 h at least to get around. It seems like forest than urban park. Clean and cozy, there are many playgrounds for kids, many places to eat, great for picnic

(continued)

Table 4.1 (continued)

No	Park name	Location coordinates	Area, % Natural, manicured, unkempt	Park age	Size, m^2	Park description
6	Kirov Garden	55.785683° 49.112507°	30 40 30	61	10,286	Central public garden with the fountain, a lot of people walk through every day. Clean park, located next to an elite residential complex
7	Shkolnikov public garden	55.822214° 49.116643°	40 50 10	5	13,637	Near to the school, there are small lake too. Many types of ornamental shrubs are grown in the park. The lawn is mowed regularly
8	«Sosnovaya Roshcha» Park	55.824225° 49.089368°	70 30 0	~ 50	86,011	Clean and cozy, there are many playgrounds for kids, comfortable for walking and doing yoga
9	«Aktash» Park	55.794808° 49.230825°	40 15 45	4	9144	Small park next to multi-story apartments and the private sector. it's not popular park. There are dog's training ground too
10	«Muzykalnyi» public garden	55.790177° 49.222738°	15 70 15	~ 10	10,117	The public garden is located next to the sports center; many young people train here. Football, basketball playgrounds. Near garden the multi-story buildings

(continued)

Table 4.1 (continued)

| No	Park name	Location coordinates	Area, % Natural, manicured, unkempt	Park age	Size, m^2	Park description
11	«Dubovyi kardon» public garden	55.750428° 49.236008°	30	~ 15	5333	Small public garden, only oak trees grow in this park, there are no playgrounds
			10			
			60			
12	Tat'yanin public garden	55.783665° 49.110683°	30	< 10	1475	Public garden near a car highway, there are no playgrounds, near to church
			10			
			60			
13	«Millenium» Park	55.78359° 49.123183°	15	16	52,172	Park is located at the center of Kazan. The big park with fountain. The park has lots of benches to relax on and admire the view. No playgrounds
			65			
			20			
14	Public garden (Peterburgskaya street)	55.782852° 49.130877°	30	10	1957	Small public garden next to five-story office building
			40			
			30			
15	Leninskiy Garden	55.794019° 49.123481°	30	131	25,608	Park is located at the center of Kazan. Leninsky park is situated next to university. There is a beautiful fountain in the middle of the park. No playgrounds
			50			
			20			
16	Memorial of Memory and Glory (Aisha village, Zelenodolsk region)	55.869668° 48.629383°	35	–	4172	Small public garden in the center of Aisha village
			15			
			50			

Table 4.1 (continued)

No	Park name	Location coordinates	Area, % Natural, manicured, unkempt	Park age	Size, m²	Park description
17	Public garden next to multistorey building (Komarova street)	55.85801° 48.564893°	30 10 60	–	3142	Public garden in the center of Zelenodolsk, there is a little fountain
18	N.Altynov public garden	55.854286° 48.553947°	40 20 40	6	6533	This small park famous for a tank weighing 40 tons, which stand there. Next to multi-story buildings
19	Green area opposite «Temple of the First Apostles Peter and Paul»	55.871510° 48.548155°	15 85 0	130	3137	Small green area next to the temple
20	Temple of the First Apostles Peter and Paul	55.871269° 48.547893°	10 90 0	130	4489	Area of the temple is small but well-organized
21	Public park (Kosmonavtov street)	55.848502° 48.505101°	15 85 0	> 10	~ 7000	Most-visited park in Zelenodolsk
22	Summer cafe (Karl Marks street)	55.849247° 48.510100°	40 0 60	> 10	300	It is a part of big park. This summer cafe has been closed for a long time. So no one walks here, as the grass is tall

Table 4.1 (continued)

No	Park name	Location coordinates	Area, % Natural, manicured, unkempt	Park age	Size, m²	Park description
23	Public park (near lake)	55.851756° 48.508549°	40 0 60	5–10	~ 2500	This green area can hardly be called a city park. This place is not completed, has a bench and gazebo, but it is difficult to get here. The park is very unkempt
24	Park «Rodina»	55.845695° 48.490492°	30 70 0	–	22,040	Clean and cozy, there are many playgrounds for kids, comfortable for walking. Next to school
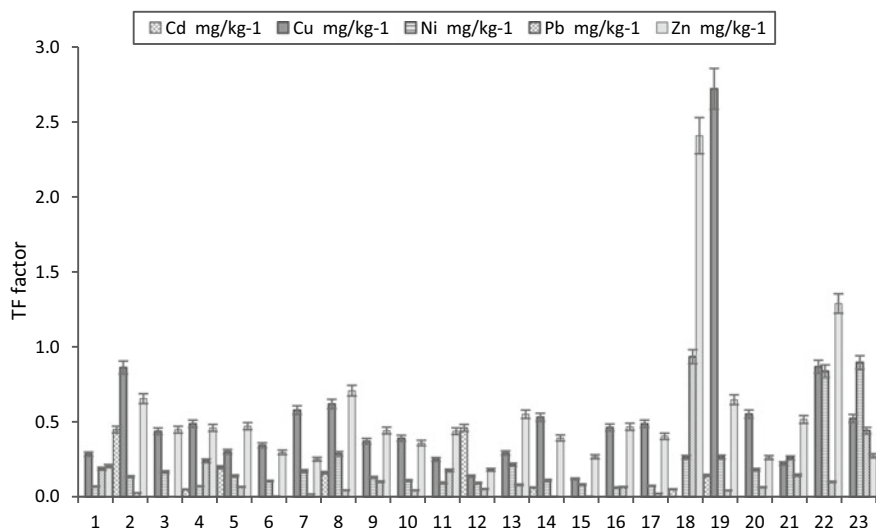
Fig. 4.5 Transfer factor (TF) found in plants samples in Kazan (1–15) and Zelenodolsk (9–24) cities (Russia)

References

Ajmone-Marsan F, Biasioli M (2010) Trace elements in soils of urban areas. Water Air Soil Pollut 1–4(213):121–143

Aleksander-Kwaterczak U, Rajca A (2015) Urban soil contamination with lead and cadmium in the playgrounds located near busy streets in Cracow (South Poland). Geol Geophys Environ 1(41):7

Alloway BJ (2013) Sources of heavy metals and metalloids in soils, pp 11–50

American Society of Agronomy (1982) Methods of soil analysis part 2. Chemical and microbiological properties. American Society of Agronomy, pp 785–787

Andrews SS, Karlen DL, Mitchell JP (2002) A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agr Ecosyst Environ 1(90):25–45

Argyraki A, Kelepertzis E (2014) Urban soil geochemistry in Athens, Greece: the importance of local geology in controlling the distribution of potentially harmful trace elements. Sci Total Environ 1(482–483):366–377

Aronson MFJ et al (2017) Biodiversity in the city: key challenges for urban green space management. Front Ecol Environ 15(4):189–196

Bae J, Ryu Y (2017) Spatial and temporal variations in soil respiration among different land cover types under wet and dry years in an urban park. Landsc Urban Plan 167:378–385

Bani A, Osmani M, Hoxha B (2015) Heavy metals and Ni phytoextractionin in the metallurgical area soils in Elbasan. Albanian J Agric Sci 4(14):414–419

Brtnický M et al (2019) Assessment of phytotoxicity, environmental and health risks of historical urban park soils. Chemosphere 220:678–686

Callender E, Rice KC (2000) The urban environmental gradient: anthropogenic influences on the spatial and temporal distributions of lead and zinc in sediments. Environ Sci Technol 2(34):232–238

Chen X et al (2020) A review on remediation technologies for nickel-contaminated soil. Hum Ecol Risk Assess 3(26):571–585

Doan HN et al (2013) Analysis community level physiological profile of bacteria in Nha Trang Bay in dry season applying Biolog Ecoplates. Proceedings Of Vast - Ird Symposium On Marine Science: 403–410

Ediene V, Umoetok S (2017) Concentration of heavy metals in soils at the municipal dumpsite in Calabar metropolis. Asian J Environ Ecol 2(3):1–11

Eshaghi RJ, Manthey M, Mataji A (2009) Comparison of plant species diversity with different plant communities in deciduous forests. Int J Environ Sci Technol 3(6):389–394

Francini G et al (2018) Soil biota in boreal urban greenspace: Responses to plant type and age. Soil Biol Biochem 118:145–155

Gallego JLR, Ordóñez A, Loredo J (2002) Investigation of trace element sources from an industrialized area (Avilés, northern Spain) using multivariate statistical methods. Environ Int 7(27):589–596

Galušková I et al (2014) Lead isotope composition and risk elements distribution in urban soils of historically different cities Ostrava and Prague, the Czech Republic. J Geochem Explor PB 147:215–221

Garland JL, Mills AL (1991) Classification and characterization of heterotrophic microbial communities on the basis of patterns of community-level sole-carbon-source utilization. Appl Environ Microbiol 8(57):2351–2359

Gilbert OL (1989) The ecology of urban habitats. O. L. Gilbert, London, p 450

Gomez E, Ferreras L, Toresani S (2006) Soil bacterial functional diversity as influenced by organic amendment application. Biores Technol 13(97):1484–1489

Grimm NB et al (2008) Global change and the ecology of cities. Science 319(5864):756–760

Gu YG, Gao YP, Lin Q (2016) Contamination, bioaccessibility and human health risk of heavy metals in exposed-lawn soils from 28 urban parks in southern China's largest city, Guangzhou. Appl Geochem 67:52–58

Guala SD, Vega FA, Covelo EF (2010) The dynamics of heavy metals in plant-soil interactions. Ecol Model 8(221):1148–1152

Haq SMA (2011) Urban green spaces and an integrative approach to sustainable environment. J Environ Prot 5(2):601–608

Hermy M, Cornelis J (2000) Towards a monitoring method and a number of multifaceted and hierarchical biodiversity indicators for urban and suburban parks. Landsc Urban Plan 3–4(49):149–162

Hutton EA et al (2004) Validation of bismuth film electrode for determination of cobalt and cadmium in soil extracts using ICP-MS. Talanta 4(63):849–855

Ji W et al (2012) Identifying the criteria of cadmium pollution in paddy soils based on a field survey. Energy Proc 16:27–31

Johnson CC, Demetriades A (2011) Urban geochemical mapping: a review of case studies in this volume, pp 7–27

Kabata-Pendias A (2010) Trace elements in soils and plants, 4th edn. A. Kabata-Pendias, pp 1–520

Karim Z, Qureshi BA (2014) Health risk assessment of heavy metals in urban soil of Karachi, Pakistan. Human Ecol Risk Assess 3(20):658–667

Kumar U et al (2017) Variation of functional diversity of soil microbial community in sub-humid tropical rice-rice cropping system under long-term organic and inorganic fertilization. Ecol Ind 73:536–543

Lacatusu R (2000) Appraising levels of soil contamination and pollution with heavy metals

Li F et al (2013) Changes in soil microbial biomass and functional diversity with a nitrogen gradient in soil columns. Appl Soil Ecol 64:1–6

Li L et al (2014a) Release of cadmium, copper and lead from urban soils of Copenhagen. Environ Pollut 187:90–97

Li P et al (2014b) Pollution evaluation and health risk assessment of heavy metals from atmospheric deposition in Lanzhou. Huanjing Kexue/environ Sci 3(35):1021–1028

Li Z, Wu X, Chen B (2007) Changes in transformation of soil organic c and functional diversity of soil microbial community under different land uses. Agric Sci China 10(6):1235–1245

Li G et al (2018) Urban soil and human health: a review. Eur J Soil Sci 69(1):196–215

Liu W et al (2012) Effect of veterinary oxytetracycline on functional diversity of soil microbial community. Plant Soil Environ 7(58):295–301

Ljung K, Selinus O, Otabbong E (2006) Metals in soils of children's urban environments in the small northern European city of Uppsala. Sci Total Environ 2–3(366):749–759

Lu Y et al (2007) Chemical fractionation of heavy metals in urban soils of Guangzhou, China. Environ Monit Assess 1–3(134):429–439

Maddaloni M et al (1998) Bioavailability of soilborne lead in adults, by stable isotope dilution. Environ Health Perspect 6:1589–1594

Madrid L, Díaz-Barrientos E, Madrid F (2002) Distribution of heavy metal contents of urban soils in parks of Seville. Chemosphere 10(49):1301–1308

McIntyre NE (2000) Ecology of urban arthropods: a review and a call to action. Ann Entomol Soc Am 93(4):825–835

Mielke HW et al (2019) The concurrent decline of soil lead and children's blood lead in New Orleans. Proc Natl Acad Sci USA 44(116):22058–22064

Monard C et al (2016) Habitat generalists and specialists in microbial communities across a terrestrial-freshwater gradient. Sci Rep 6:1–10

Morel J-L, Heinrich AB (2008) SUITMA—soils in urban, industrial, traffic, mining and military areas. J Soils Sediments 4(8):206–207

Mulligan CN, Yong RN, Gibbs BF (2001) Remediation technologies for metal-contaminated soils and groundwater: an evaluation. Eng Geol 1–4(60):193–207

Nazir R et al (2015) Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam Kohat. J Pharm Sci Res 3(7):89–97

Nganje TN et al (2020) The concentration, distribution and health risk from potentially toxic elements in the soil–plant–water system developed on black shales in SE Nigeria. J Afr Earth Sci 165:103806

Nielsen AB et al (2014) Species richness in urban parks and its drivers: a review of empirical evidence. Urban Ecosyst 1(17):305–327

Page-dumroese DS (2020) Forest and rangeland soils of the United States under changing conditions. D.S. Page-dumroese

Penteado JO et al (2021) Health risk assessment in urban parks soils contaminated by metals, Rio Grande city (Brazil) case study. Ecotoxicol Environ Safety 208:111737

Ricotta C (2005) Through the jungle of biological diversity. Acta Biotheor 1(53):29–38

Romic M, Romic D (2003) Heavy metals distribution in agricultural topsoils in urban area. Environ Geol 7(43):795–805

Różański SŁ et al (2018) Heavy metal content and mobility in urban soils of public playgrounds and sport facility areas, Poland. Chemosphere 212:456–466

Scharenbroch BC, Lloyd JE, Johnson-Maynard JL (2005) Distinguishing urban soils with physical, chemical, and biological properties. Pedobiologia 4(49):283–296

Simpson EH (1949) Measurement of diversity. Nature 163(4148):688

Sörme L, Bergbäck B, Lohm U (2001) Century perspective of metal use in urban areas—a case study of Stockholm. Water Air Soil Pollut Focus 1:197–211

Takada Y (1954) On the mathematical theory of communication. Jpn J Psychol 2(25):110–117

Tijhuis L, Brattli B, Sæther OM (2002) A geochemical survey of topsoil in the City of Oslo, Norway. Environ Geochem Health 1(24):67–94

Tomitaka M et al (2021) Species richness and flower color diversity determine aesthetic preferences of natural-park and urban-park visitors for plant communities. Environ Sustain Indic 11(2021):100130

Tresch S et al (2018) Urban soil quality assessment-a comprehensive case study dataset of urban garden soils. Front Environ Sci 6(136)

Uzu G et al (2009) Study of lead phytoavailability for atmospheric industrial micronic and submicronic particles in relation with lead speciation. Environ Pollut 4(157):1178–1185

Vig K et al (2003) Bioavailability and toxicity of cadmium to microorganisms and their activities in soil: a review. Adv Environ Res 1(8):121–135

Wang F et al (2020) Contamination characteristics, source apportionment, and health risk assessment of heavy metals in agricultural soil in the Hexi Corridor. CATENA 191:104573

Wang Z et al (2022) Legacy of anthropogenic lead in urban soils: Co-occurrence with metal(loids) and fallout radionuclides, isotopic fingerprinting, and in vitro bioaccessibility. Sci Total Environ 806:151276

Wei X et al (2018) Expansion of rice enzymatic rhizosphere: temporal dynamics in response to phosphorus and cellulose application. Plant Soil 445:169–181

World Health Organization (WHO) (1996) Permissible limits of heavy metals in soil and plants. Geneva, Switzerland

Xue D et al (2008) Soil microbial community structure in diverse land use systems: a comparative study using biolog, DGGE, and PLFA Analyses. Pedosphere 5(18):653–663

Yan Z et al (2019) Impervious surface area is a key predictor for urban plant diversity in a city undergone rapid urbanization. Sci Total Environ 650:335–342

Yang Y et al (2006) Microbial indicators of heavy metal contamination in urban and rural soils. Chemosphere 11(63):1942–1952

Zakirova J, Khusnutdinova S (2018) The problems of formation and conservation of the green frame (green carcass) of the satellite city (on the example of Zelenodolsk). IOP Conf Ser Earth Environ Sci 107:012139.

Zhang Q et al (2019) Variation of soil anaerobic microorganisms connected with anammox processes by 13C-phospholipid fatty acid analysis among long-term fertilization regimes in a crop rotation system. Appl Soil Ecol 133:34–43

Zhao L et al (2014) Source identification and health risk assessment of metals in urban soils around the Tanggu chemical industrial district, Tianjin, China. Sci Total Environ 468–469:654–662

Zhong M, Jiang L (2017) Refining health risk assessment by incorporating site-specific background concentration and bioaccessibility data of Nickel in soil. Sci Total Environ 581–582:866–873